

Patent claims

1. Production of a multilayer system with cover layer system, in particular for a reflective optical element for the extreme ultraviolet to soft X-ray wavelength range, comprising the following steps:
 1. designing a coating design for the multilayer system with cover layer system;
 2. coating a substrate with the multilayer system with cover layer system;
 3. spatially resolved measurement of the coated substrate with regard to reflectivity and photoelectron current at at least one surface point;
 4. comparing the measurement data with data modeled for different thicknesses of the layers of the cover layer system and/or of the layers of the multilayer system for determining the thickness distribution achieved by the coating;
 5. if appropriate adapting the coating parameters and repeating steps 2 to 5 until the coated thickness distribution corresponds to the design.
2. Production method according to Claim 1, **characterized in that** the thickness distribution of the cover layer system is determined in step 4.

3. Production method according to Claim 1 or 2, **characterized in that** a design is designed in which the thickness distribution of the cover layer system is constant over the entire surface.
4. Production method according to Claim 1 or 2, **characterized in that** a design is designed in which the thickness distribution of the cover layer system is variable over the surface.
5. Production method according to any of Claims 1 to 4 comprising the following additional steps:
 6. simulation calculation of an optical system in which the multilayer system is used, and comparing the simulation results with specifications established beforehand;
 7. if appropriate adapting the layer design and repeating steps 2 to 7 until the multilayer system with cover layer system fulfills the specifications.
6. Production method according to any of Claims 1 to 5 comprising the following additional steps:
 - 6'. testing the multilayer system with cover layer system in radiation operation and comparing the test results with specifications established beforehand;
 7. if appropriate adapting the layer design and repeating steps 2 to 5, 6 and/or 6', 7 until the multilayer system with cover layer system fulfills the specifications.
7. Reflective optical element for the extreme ultraviolet to soft X-ray wavelength range, produced according to Claims 1 to 6.

8. EUV lithography appliance comprising at least one reflective optical element according to Claim 7.
9. Method for the production of a reflective optical element for the extreme ultraviolet to soft X-ray wavelength range comprising a cover layer system having a constant thickness, comprising the following steps:
 1. designing a coating design for the multilayer system with cover layer system;
 2. coating a substrate with the multilayer system with cover layer system;
 3. measurement of the coated substrate with regard to reflectivity and photoelectron current at at least one surface point;
 4. comparing the measurement data with data modeled for different thicknesses of the layers of the cover layer system for determining the thickness distribution achieved by the coating;
 5. if appropriate adapting the coating parameters and repeating steps 2 to 5 until the coated thickness distribution corresponds to the design.
10. Production method according to Claim 9 comprising the following additional steps:

6. simulation calculation of an optical system in which the multilayer system is used, and comparing the simulation results with specifications established beforehand;
 7. if appropriate adapting the layer design and repeating steps 2 to 7 until the multilayer system with cover layer system fulfills the specifications.
11. Production method according to Claim 9 or 10 comprising the following additional steps:
- 6'. testing the multilayer system with cover layer system in radiation operation and comparing the test results with specifications established beforehand;
 7. if appropriate adapting the layer design and repeating steps 2 to 5, 6 and/or 6', 7 until the multilayer system with cover layer system fulfills the specifications.
12. Reflective optical element for the extreme ultraviolet to soft X-ray wavelength range comprising a cover layer system having a constant thickness produced in accordance with the method according to Claims 9 to 11.
13. EUV lithography appliance comprising at least one reflective optical element according to Claim 12.
14. Reflective optical element for the extreme ultraviolet to soft X-ray wavelength range composed of a multilayer system with cover layer system comprising at least one layer composed of a transition metal or of a transition-metal-containing alloy or

mixture or compound and optimized for an operating wavelength in the extreme ultraviolet to soft X-ray wavelength range, **characterized in that** at least one layer or cover layer thickness is chosen in such a way that, upon irradiation with the operating wavelength, a standing electromagnetic wave forms in such a way that it has an intensity maximum in the region of the free interface of the reflective optical element.

15. Reflective optical element according to Claim 14, **characterized in that** the at least one layer or cover layer thickness is chosen in such a way that the intensity maximum lies on the vacuum side of the free interface of the reflective optical element.
16. Lithography appliance comprising at least one reflective optical element according to Claim 14 and 15 and comprising in an evacuable housing and at least two feed lines which open in the region of the reflective optical element and serve for feeding an oxidizing gas or gas mixture and a reducing gas or gas mixture.
17. Method for the operation of a reflective optical element according to Claim 14 or 15 in a closed system comprising a residual gas atmosphere composed of a hydrocarbon, water and oxygen, in which, at the beginning of irradiation with the operating wavelength, the hydrocarbon partial pressure is increased in such a way that carbon deposits on and/or at the topmost layer, such that the intensity maximum of the standing electromagnetic wave that forms is situated at the free interface.
18. Method according to Claim 17, **characterized in that** the position of the intensity maximum relative to the free interface is monitored during operation by measurement of the photoelectron

current and the partial pressures of hydrocarbon, water and oxygen are readjusted in such a way that the position of the intensity maximum becomes constant with respect to the free interface.

19. Method according to Claim 18, **characterized in that** the partial pressures are readjusted in such a way that the intensity maximum lies on the free interface.
20. Method for the operation of a reflective optical element according to Claims 14 to 15 in a closed system comprising a residual gas atmosphere having a reducing gas fraction and an oxidizing gas fraction, in which the partial pressures of the gas fractions are set in such a way that oxidizing and reducing reactions are in equilibrium at the topmost cover layer.
21. Method according to Claim 20, **characterized in that** an oxygen-atom-comprising gas or gas mixture is used as oxidizing gas fraction in the residual gas atmosphere.
22. Method according to Claim 20 or 21, **characterized in that** at least one hydrocarbon is used as reducing gas fraction in the residual gas atmosphere.
23. Method for the operation of a reflective optical element for the extreme ultraviolet to soft X-ray wavelength range composed of a multilayer system comprising a topmost cover layer composed of carbon and/or an oxide in a closed system comprising a residual gas atmosphere having a reducing gas fraction and an oxidizing gas fraction, in which the partial pressures of the gas fractions are set in such a way that oxidizing and reducing reactions are in equilibrium at the topmost cover layer.

24. Method according to Claim 23, **characterized in that** a reflective optical element is used in which at least one layer or cover layer thickness is chosen in such a way that, upon irradiation with the operating wavelength, a standing electromagnetic wave forms in such a way that it has an intensity minimum in the region of the free interface of the optical element.
25. Method according to Claim 24, **characterized in that** an oxygen-atom-comprising gas or gas mixture is used as oxidizing gas fraction in the residual gas atmosphere.
26. Method according to any of Claims 23 to 25, **characterized in that** at least one hydrocarbon is used as reducing gas fraction in the residual gas atmosphere.
27. EUV lithography apparatus comprising at least one reflective optical element for the extreme ultraviolet to soft X-ray wavelength range composed of a multilayer system comprising a topmost cover layer composed of carbon and/or an oxide, in which at least one layer or cover layer thickness is chosen in such a way that, upon irradiation with the operating wavelength, a standing electromagnetic wave forms in such a way that it has an intensity minimum in the region of the free interface of the optical element, comprising an evacuable housing, in which the reflective optical element is arranged, and at least two feed lines which open in the region of the reflective optical element and serve for feeding an oxidizing gas or gas mixture and a reducing gas or gas mixture.

28. EUV lithography apparatus comprising at least one photoelectron detector comprising at least one tunable monochromator in the beam path, such that the incident wavelength can be altered, in particular can be changed between the operating wavelength and at least one used wavelength.
29. EUV lithography apparatus according to Claim 29 comprising at least one photoelectron detector comprising means for setting a residual gas atmosphere within the EUV lithography appliance.
30. EUV lithography apparatus according to Claim 28 or 29,
characterized in that it has a cleaning reticle alongside an operating reticle.
31. EUV lithography apparatus according to any of Claims 28 to 30,
characterized in that it has a collimator and/or at least one diaphragm for geometrical beam shaping.
32. EUV lithography apparatus according to any of Claims 28 to 31,
characterized in that it has devices for setting local partial pressure differences.
33. Method for the operation of an EUV lithography apparatus according to any of Claims 28 to 32, in which, at predetermined times, a changeover is made from radiation operation to the detection mode by virtue of the fact that
 1. in a targeted manner, the location to be examined is irradiated and, with tuning of the monochromator, the photoelectron current and, if appropriate, the reflectivity are measured in a manner dependent on the wavelength;

2. the contamination state is determined from the determination of the spectral profile of photoelectron current in the range of maximum reflectivity and/or the comparison of the measured photoelectron current data with data modeled for different contamination states.
34. Method according to Claim 33, **characterized in that** in the case of first controlled variables being exceeded in the case of the contamination state, the residual gas atmosphere is modified to the effect that the contamination is reduced.
35. Method according to Claim 33, **characterized in that** in the case of second controlled variables being exceeded in the case of the contamination state, the composition of the residual gas atmosphere and the cross section and position of the incident beam are modified to the effect that material is locally added and/or removed in a defined manner.
36. Method according to any of Claims 33 to 35, **characterized in that**, the spectral and/or spatial properties of the illumination spot is altered with the aid of a cleaning reticle.
37. Method according to any of Claims 33 to 36, **characterized in that** the spatial and/or spectral properties of the illumination spot are altered with the aid of a collimator and/or at least one diaphragm.
38. Method according to any of Claims 33 to 37, **characterized in that** the partial pressures are altered at least at the illuminated location during the measurement and/or the addition and/or removal within the lithography appliance.